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Assessment of the 1987 Fishery for Snow Crab, Chionoecetes opilio, Around the Atlantic Coast of Cape Breton Island

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ABSTRACT

Biological monitoring data (based on fishermen's logbooks, sales slips statistics, and commercial catch sampling) were examined for the Cape Breton Island (Atlantic coast, Areas 2 to 6) snow crab fishery in 1987. Assessments for each stock were made by comparison of the monitoring data against historical patterns. Since 1978 the snow crab fisheries in Areas 2 to 6 have been based on a resource with low or sporadic recruitment. The accumulated virgin biomass was rapidly extinguished in the initial years of fishing. Management dropped catch controls for the fishery in 1982 to allow fishermen to take advantage of whatever productivity occurs from time to time on an opportunistic basis. The minimum legal size of 95 mm carapace width was thought to confine exploitation to males that had been mature for 1 to 3 yr. Hence, the reproductive potential of the resource was believed to be protected. However, up to approximately 46% of the landed males sampled during 1987 were morphometrically immature. Although the longer-term biological implications of this situation remain unclear, virtually all of the mature females sampled through the 1987 fishing season were carrying eggs. Morphometrical analyses of data from at-sea sampling also revealed that large numbers of males had attained a terminal molt below the legal minimum size; an innovative strategy to harvest this 'wasted' resource on an experimental basis may be desirable.

The overall status of stocks in Areas 2 to 6 in 1987 appears to have improved over the 1986 situation, which is a further reversal over the collapsed state noted in previous years. A pulse of males first detected in 1985 continued recruiting into the commercial stocks prior to the 1987 fishing season and increased fishable biomass over 1986 levels in all areas. A strong market demand for snow crab resulted in a doubling of fishing effort; this, coupled with higher catch rates, resulted in a dramatic rise in landings. Sixty-four of 104 licensed vessels were active, and their recorded catch (360.3 t) was 346% of the 1986 value (32 vessels: 104.2 t) but still only 59% of the 1982 value (67 vessels: 615.4 t). Stock dynamics and logbook returns permitted estimates of commercial biomass and exploitation rate for all areas by Leslie analyses.

Fishing activity was minor in Area 2 (3 vessels: 529 kg). Landings of 59.8 t were recorded from sales slips for the 21 active vessels in Area 3. All of the 15 active vessels in Area 4 fished inshore and recorded total landings of 58.7 t, by sales slips. Utilizing the logbooks for vessels fishing in the combined Areas 2, 3, and 4 (inshore), mean CPUE was 8.2 kg trap haul^{-1}, compared to the mean of 3.33 kg trap haul^{-1} recorded in 1986. Total available biomass for the combined inshore Areas 2, 3, and 4 was estimated at 229 t, and the exploitation rate at 46%.

Sales slips in Area 5 indicated landings of 157.4 t, a sharp increase from the 44.0 t landed in 1986. Logbooks from 11 of the 14 active vessels reported landings of 119.3 t. The mean CPUE of 26.24 kg trap haul^{-1} was almost double that for 1986 (14.15 kg trap haul^{-1}) and the highest experienced in the area since 1982. Leslie estimates gave available commercial biomass and exploitation rate for the season as 293 t and 41%, respectively.

Logbooks in Area 6 documented catches of 77.8 t for 9 of the 11 active vessels; landings of 83.9 t were recorded by sales slips. Mean CPUE was 12.91 kg trap haul^{-1}, a slight increase over the 1986 value of 11.90 kg trap haul^{-1}. Total available biomass and exploitation rate were estimated at 182 t and 43%, respectively.

The 1987 assessment for Areas 2 to 6 does not appear to justify changes in current management strategy. Given the erratic production dynamics of these stocks over the past decade, and notwithstanding an influx of recruitment that may continue in 1988, there appears to be no rationale for reintroducing catch controls for the 1988 season.

RESUME

Les données de surveillance biologique (fondées sur les journaux de bord des pêcheurs, les statistiques sur les bordereaux de vente et l'échantillonnage des pêches commerciales) ont été examinées pour la pêcherie de crabe des neiges de 1987 à l'île du Cap-Breton (côte atlantique, zones 2 à 6). Chaque stock a été évalué par comparaison des données obtenues et des tendances antérieures. Depuis 1978, la pêche du crabe des neiges dans les zones 2 à 6 exploite une ressource dont le recrutement est faible ou sporadique. la biomasse vierge accumulée a été rapidement épuisée dès les premières années de l'exploitation. Les gestionnaires ont levé en 1982 les restrictions imposées pour permettre aux pêcheurs de profiter de la productivité qui se manifeste de façon occasionnelle. On pensait que la taille minimum légale de 95 mm de largeur de la carapace restreindrait l'exploitation aux mâles matures depuis 1 à 3 ans, ce qui était censé protéger le potentiel de reproduction de cette ressource. Cependant, jusqu'à a 46% environ des mâles débarqués échantillonnés en 1987 étaient morphométriquement immatures. Bien qu'on ne connaisse pas les incidences biologiques à long terme de cette situation, presque toutes les femelles matures échantillonnées pendant la saison de pêche de 1987 portaient des oeufs. Des analyses morphométriques des données provenant de l'échantillonnage en mer ont aussi révélé qu'un grand nombre de mâles avaient atteint leur mue terminale au-dessous de la taille légale minimum; il serait bon de mettre au point une stratégie innovatrice pour exploiter cette ressource "perdue".

La situation générale des stocks des zones 2 à 6 semble s'être améliorée en 1987 par rapport à celle de 1986, ce qui indique un renversement de tendance par rapport à l'effondrement observé les années précédentes. Une poussée de mâles repérée pour la première fois en 1985 a continué à entrer dans la phase exploitable avant la saison de pêche de 1987, ce qui a augmenté la biomasse exploitable dans tous les secteurs par rapport à 1986. La forte demande de crabe des neiges sur les marchés a provoqué un doublement de l'effort de pêche. Ce facteur, combiné à une augmentation des taux de capture, a causé une hausse spectaculaire des débarquements. Sur les 104 bateaux dotés de permis, 64 ont pêché le crabe, et leurs prises enregistrées (360.3 t) étaient égales à 346 % de celles de 1986 (32 bateaux: 104.2 t) mais ne dépassaient pas 59 % de celles de 1982 (67 bateaux : 615.4 t). La dynamique du stock et les données des journaux de bord ont permis d'estimer par la méthode de Leslie la biomasse commerciale et le taux d'exploitation pour toutes les zones.

L'activité de pêche est restée faible dans la zone 2 (3 bateaux : 529 kg). Des débarquements de 59.8 t ont été enregistrés à partir des bordereaux de vente des 21 bateaux actifs dans la zone 3. Les 15 bateaux actifs dans la zone 4 ont pêché dans les eaux côtières et ont rapporté des débarquements totalisant 58.7 t d'après les bordereaux de vente. A partir des journaux de bord des bateaux pêchant dans les zones 2, 3 et 4 combinées (eaux côtières), les CPUE moyennes étaient de 8.2 kg/casier levés, contre une moyenne de 3.33 kg/casier levés en 1986. On estime pour les zones côtières 2, 3 et 4 combinées la biomasse totale exploitable à 229 t et le taux d'exploitation à 46 %.

Les bordereaux de vente de la zone 5 ont indiqué des débarquements de 157.4 t, soit une nette augmentation par rapport aux 44.0 t débarquées en 1986. Les journaux de bord de 11 des 14 bateaux actifs ont enregistré des débarquements de 119.3 t. Les CPUE moyennes de 26.24 kg/casier levés^{-1} étaient presque le double de celles de 1986 (14.15 kg/casier levés^{-1}), et les plus élevées notées dans la région depuis 1982. Les estimations selon la méthode de Leslie donnent une biomasse commerciale exploitable de 293 t et un taux d'exploitation de 41 % pour la saison.

Les journaux de bord de la zone 6 ont enregistré des prises de 77.8 t pour 9 des 11 bateaux actifs; les bordereaux de vente donnent des débarquements de 83.9 t. Les CPUE moyennes étaient de 12.91/kg casier levés^{-1}, soit une légère augmentation par rapport à 1986 (11.90 kg/casier levés^{-1}). On estime respectivement la biomasse totale exploitable et le taux d'exploitation à 182 t et 43 %.

L'évaluation de 1987 pour les zones 2 à 6 ne semble pas justifier une modification de la stratégie actuelle de gestion. Etant donné la dynamique erratique de production de ces stocks depuis une dizaine d'années, et sans tenir compte de la hausse du recruitment qui peut se maintenir en 1988, il ne semble pas justifié de rétablir des restrictions à la capture pour la saison 1988.

INTRODUCTION

The directed inshore fishery for snow crab, Chionoecetes opilio, off Cape Breton Island was started in 1966 on the northwestern coast. Between 1976 and 1978, seven inshore areas were defined around Cape Breton Island (Fig. 1) for exclusive exploitation by inshore boats under 45 ft (13.7 m) in length. Between 1977 and 1979, landings rose markedly in phase with effort and the expansion of the fishery to approximately 180 inshore vessels operating around most of the Island (Elner 1982a). However, by 1982 it became apparent that the snow crab stocks along the Atlantic coast of Cape Breton Island (Areas 2 to 6, Scotia-Fundy Region) have only low, or sporadic, recruitment and that the accumulated virgin biomass had been largely removed by fishing. In contrast, on the Gulf of St. Lawrence coast of the Island (Areas 1 [19] and 7 [18], Gulf Region) larger production levels conferred relative stability to the commercial biomass and landings (Elner 1982a; Davidson et al. 1985). As the productivity of the Atlantic coast resource appeared too low and erratic to allow for a strategy of biomass stabilization, management dropped catch controls for the fishery in 1982 to allow existing fishermen to take advantage of whatever productivity occurs from time to time on an opportunistic basis. The regulatory measures remaining include strict licensing controls, a 30 trap/vessel limit, a relatively short fishing season (10 wk, July-September), and a minimum legal size of 95 mm carapace width (CW).

The minimum legal size regulation of 95 mm CW was thought to confine exploitation to males mature for 1 to 3 yr and thus theoretically protect the reproductive potential of the resource (Elner and Robichaud 1983a; Elner and Gass 1984). However, up to approximately 50% of the commercial-sized males sampled in Areas 3, 5, and 6 during 1986 were morphometrically immature (Elner and Robichaud 1987). Furthermore, both male and female snow crabs in eastern Canada are now considered to have a terminal molt to morphometric maturity (O'Halloran 1985; Conan and Comeau 1986). The size, and presumably age, at which this may occur is variable. Which factors influence when an individual crab undergoes its terminal molt are unknown; but for males, the size of terminal molt can be 50-150 mm CW. The implications of this new knowledge on snow crab management are still unclear.

The present paper assesses the status of the snow crab fishery in Areas 2, 3, 4, 5, and 6* for 1987. Such annual assessments form the biological basis for management of the various Canadian fisheries for snow crab.

MATERIALS AND METHODS

Cape Breton Island snow crab fishermen have been required to maintain logbooks for each fishing season since 1978. The logbooks from the 1987 season provided catch, effort, and CPUE data for each area over time. In contrast to many previous years, exploitation rates and biomass could be estimated by Leslie analysis for all areas in 1987. Sales slips provided supplementary landing statistics and also served to check logbook coverage. To improve trap location information given in logbooks, fishermen have been provided large-scale grid charts since 1983 and requested to indicate the grid number(s) corresponding to their fishing area(s). For detailed accounts of snow crab logbook format and Leslie analysis see Elner (1982b) and Mohn and Elner (1988).

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*Revised Management Areas: 20, 21, 22, 23, and 24, respectively.

Port and at-sea sampling were carried out on an opportunistic basis throughout the fishing season in Areas 2, 3, 4, 5, and 6, to monitor the size-frequency distribution and shell-hardness profile of commercial catches (see Appendix I for recording sheet). Snow crab size was determined by measurement of carapace width (CW) across the widest part of the carapace. Shell hardness was assessed subjectively as "hard," "intermediate," or "soft" by applying thumb pressure across a chela.

Chela height (Fig. 2) was measured for male snow crabs to continue research into morphometrics and size at maturity. Conan and Comeau (1986) and O'Halloran (1985) detail the relationship between chela allometry and morphometric maturity. In summary, when logarithms of chela height are plotted against the logarithms of carapace width, morphometrically immature crabs form a swarm of data points distinct from morphometrically mature crabs. The major axes of the swarms are parallel, and area-specific cutting lines effectively separate the two swarms; data points for mature crabs appear above the cutting line and points for immature crabs fall underneath. Details of the discriminant function analyses and various cutting line equations (produced by M. Comeau, DFO, Gulf Region) are presented in Appendix II.

The status of snow crab stocks in Areas 2, 3, 4, 5, and 6 for 1987 was assessed on the basis of fishermen's logbooks, sales slips, commercial catch sampling, as well as historical monitoring data. (Appendix III shows the relative number of logbook returns as compared to the number of active and licensed vessels for each year since 1978.)

RESULTS

The 1987 fishing season extended between July 22 to September 15 for Areas 2, 3, 4, and 5, and August 1 to September 31 for Area 6. A summary of snow crab landings, catch and effort statistics, biomass, and exploitation rates for each Area since 1978 is presented in Tables 1 and 2.

Provision of trap location information in the fishermen's logbooks was generally poor in 1987, and the data have not been utilized in this assessment. However, trapping was recorded in the following 7x5-mi grid squares (see Elner and Robichaud [1986] for grid map):

Area 3: 230, 247
Area 4: 314
Area 5: 381, 394, 395, 396, 405, 407
Area 6: 418, 434, 435, 449, 450

AREAS 2, 3, and 4 (NORTHEASTERN CAPE BRETON - INSHORE)

Port and at-sea sampling

Comparisons of the 1987 size-frequency profiles for Areas 2 and 4 (Fig. 3 and 4) against previous profiles are impractical, as these areas were not sampled in 1986. However, while the mean sizes (102.6 mm and 102.5 mm CW) for port samples (Fig. 5) taken in Area 3 in July and August 1987, respectively, are close to the August 1986 value (101.3 mm CW), the at-sea sample is considerably shifted to the right (1986: 83.9 mm CW; 1987: 101.9 mm CW). This shift may reflect the growth of a strong year-class into

the commercial size range and is commensurate with the observed increase in relative abundance (see below). Virtually all of the male and female snow crabs sampled in port and at sea in Areas 2, 3, and 4 were in a hard-shelled condition (Table 3).

Maturity

Chela height versus CW data for males in the 1987 at-sea samples in Areas 2, 3, and 4 (Fig. 6) indicate that up to 9% of the catch, including some legal-sized crabs, were morphometrically immature. Similarly, up to 11% of the legal-sized crabs sampled in port in Areas 2, 3, and 4 during July and August 1987 were morphometrically immature (Fig. 7 and 8). While the morphometrically immature crabs can be expected to molt and further contribute to production in the 1988 season, the morphometrically mature individuals, including a large proportion below the legal minimum size, cannot be expected to grow again.

Females

All 414 mature female crabs sampled in Areas 2, 3, and 4 during August 1987 were ovigerous (Table 3; Fig. 9).

Logbooks

Three fishermen were active in Area 2, 21 were active in Area 3, and 15 in Area 4. No log records were forthcoming from the Area 2 fishermen, although 14 were received from Area 3 and 12 from Area 4 (Tables 1, 2). Available records indicate that most of the fishermen were active on inshore grounds in, or adjacent to, Area 3 (Fig. 1). Thus, for assessment purposes (as in previous years) fishermen are considered to have exploited a single stock (Areas 2, 3, and 4, inshore). The offshore of Area 4, which has been exploited in previous years (Elner and Robichaud 1987) does not appear to have been fished in 1987. Landings, as recorded from sales slips and logbooks for the inshore area, were 119.0 t and 105.9 t, respectively.

Analysis of catch and effort data from the combined Areas 3 and 4 logbooks revealed a declining trend in mean weekly CPUE through the fishing season (Table 4). The mean CPUE (8.20 kg trap haul^{-1}) in 1987 was the highest recorded since 1981 and was over double the rate observed for the past three annual assessments (Fig. 10). Leslie analysis (Fig. 11) indicates that the total available commercial biomass (B_0) for the fishing season was 229,166 kg (95% confidence limits [CL]: 186,448 kg and 316,320 kg). Hence, given logbook-derived catches of 105,922 kg, 123,244 kg would have been left on the grounds at the end of the fishing season (95% CL: 80,526 kg and 210,398 kg) after an exploitation rate of 46% (95% CL: 57% and 33%). The total available biomass estimated for 1987 is an order of magnitude higher than that assessed for 1986 and the highest recorded since 1980 (Table 2).

AREA 5 (SOUTHEASTERN CAPE BRETON)

Port and at-sea sampling

Size-frequency histograms for port and at-sea sampling in Area 5 during July and August 1987 are shown in Figure 12. Comparison between port sampling histograms for 1986 (Elner and Robichaud 1987: August, mean CW = 105.0) and 1987 (August, mean CW = 115.0 mm) reveals shifts to the right, commensurate with a recruitment pulse, as observed in Areas 2, 3, and 4. However, a comparison of the sea sample for August 1986 (Elner and Robichaud 1987: mean CW = 100.3 mm) against that for August 1987 (mean CW = 94.7 mm) reveals an enigmatic shift to the left.

All male and female crabs sampled at sea and in port during the 1987 season were in a hard-shelled condition (Table 3). In-season growth and recruitment has not been recorded in Area 5 since 1978 (Elner 1982b, Elner and Robichaud 1983b; 1984; 1985; 1986; 1987).

Maturity

Plots of chela height versus CW for male crab sampled at sea and in port (Fig. 13) during the 1987 season indicate that a proportion of both the sublegal crabs (<95 mm CW) and the legal crabs (≥95 mm CW) were morphometrically immature. Again, as in Areas 2, 3, and 4, there appears a large 'sink' of terminal males below the legal minimum size. The actual distribution of the data points in Figure 13 appears similar to the pattern observed in both 1985 and 1986 (Elner and Robichaud 1986; 1987).

Females

Of the 284 mature females sampled at sea in July and August 1987, all but three were ovigerous (Table 3; Fig. 14). The high proportion of ovigerous females appears to be a reversal of the declining trend noted in previous years (Elner and Robichaud 1986) and is probably a reflection of the same recruitment pulse detected for the male crabs. Previously, a lack of recruitment had led to a "senility" phenomenon with either barren females or multiparous females with reduced egg clutches becoming increasingly common as the population aged.

Logbooks

Logbooks were received from 11 of the 14 Area 5 fishermen who set traps in 1987. Total landings derived from logbooks were 119,321 kg, as compared to 157,408 kg from sales slips statistics. Landings in 1987, according to sales slips, were 358% above the value for 1986 (43,972 kg) and over five times the level achieved in 1985 (29,171 kg); however, catches are still considerably below historical levels (Tables 1 and 2). Actual recorded effort in 1987 (4,547 trap hauls) was 160% of the 1986 value and 310% of the 1985 value (Table 2).

The overall mean CPUE value for the 1987 season (26.2 kg trap haul^{-1}) was markedly above mean values estimated for the previous 4 yr (Table 2; Fig. 15). Mean weekly CPUE values fluctuated through the fishing season but, overall, demonstrated a declining trend that was amenable to analysis by the

Leslie method (Table 4, Fig. 11). Based on Leslie analysis, the B_0 for the season was 293,354 kg (95% CL: 196,965 kg and 966,413 kg). Logbook-derived catches of 119,321 kg would have resulted in an exploitation rate of 41% (95% CL: 61% and 12%) and left 174,033 kg (95% CL: 77,644 kg and 847,092 kg) on the Area 5 grounds after the fishing season. The B_0 estimated for 1987 is considerably above that for 1986 (72.9 t), reflecting a massive influx of growth and recruitment, but remains below historical high levels (Table 2).

AREA 6 (SOUTHERN CAPE BRETON)

Port and at-sea sampling

Port and at-sea catch sampling was carried out in Area 6 during August 1987 (Fig. 16). The mean CW (108.0 mm) for the at-sea sample is close to that for the port sample (mean CW = 110.4 mm). In comparison, the port (mean CW = 115.1 mm) and at-sea (mean CW = 84.5 mm) samples in August 1986 were more clearly separated. All male and female snow crabs inspected were in a hard-shelled condition (Table 3).

Maturity

Plots of chela height versus carapace width for male snow crabs sampled at sea and in port (Fig. 17) during the 1987 season indicate that a large proportion of both the sublegal crabs (<95 mm CW) and the legal crabs (≥95 mm CW) were morphometrically immature. As in all of the other areas, there appears to be a large "sink" of sublegal crabs in terminal molt.

Females

All but four of the 247 mature female snow crabs sampled at sea in August 1987 were ovigerous (Table 3; Fig. 18).

Logbooks

The total landings from nine logbooks received from the 11 active Area 6 fishermen in 1987 amounted to 77,782 kg, as opposed to 83,931 kg recorded through the sales slip statistics system (Tables 1 and 2). Total landings were above all historical levels, and mean CPUE was the highest since 1981 (Fig. 19).

CPUE declined through the season, and the resultant pattern was amenable to analysis by the Leslie method (Table 4; Fig. 11). B_0 for the 1987 season was estimated at 181,668 kg (95% CL: 146,210 kg and 256,446 kg); and, given logbook-derived landings of 77,782 kg, exploitation rate was 43% (95% CL: 53% and 30%). By subtraction, 103,886 kg (95% CL: 68,428 kg and 178,664 kg) of commercial-sized crab remained on the Area 6 grounds at the end of the fishing season. The B_0 level estimated for 1987 is the highest ever estimated for Area 6 and is likely a reflection of the recruitment pulse noted in the other areas assessed in 1987 (Table 2). Overall, Area 6 continues to show relatively greater stability in commercial biomass and catch rates than any other snow crab ground on the Atlantic coast of Cape Breton Island.

DISCUSSION

A notable change in the dynamics of the snow crab stocks around the Atlantic coast of Cape Breton Island occurred between the end of the 1985 fishing season and commencement of the 1986 season (Elner and Robichaud 1987). Essentially, a moderately large pulse of snow crab recruited into the fisheries in Areas 2 to 6 - the first significant production noted in the system since assessments began in 1978. The present assessment indicates that the pulse continued to recruit into the system in 1987. Previously, the lack of production in the face of heavy fishing pressure had resulted in rapidly declining commercial biomass levels, excessive exploitation rates, and marginal catch rates. Consequently, annual effort and landings fell progressively between 1979 and 1985. It is probable that the upcoming recruitment pulse was detected as by-catch to a Danish seiner operating in Area 5 in July 1985 (Elner and Robichaud 1986). Size-frequency histograms of the by-catch showed immature males and females at a modal size of approximately 58 mm CW. Given the large numbers of morphometrically immature, pre-recruit males sampled in 1986 and 1987, the improved production trend seems likely to continue into the 1988 season with concommittant increases in commercial biomass and catch rates. Nevertheless, considering the erratic nature of recruitment, there appears to be no biological basis for reintroducing catch controls (TAC's). Restricting effort to the present level should not only extend to the period over which the current recruitment pulse will support the fishery but will, also, help to restrain catches close to the target harvest rate at 50-60% (Elner and Bailey 1986). The long-term prognosis for snow crab in Cape Breton remains uncertain; the fundamental biological basis to snow crab management is now acknowledged to be weak; and until "breakthroughs" in research occur, managers and biologists must continue to react to system changes as they occur rather than to plan for predicted commercial biomass levels.

Recent findings that male snow crabs mature over a wide size range and cease molting at morphometric maturity (O'Halloran 1985; Conan and Comeau 1986) have various implications for fisheries management. As documented by Elner and Bailey (1986), an expectation from the legal minimum size of 95 mm CW was that only males that had been mature for 1 to 4 yr would be harvested. Hence, as females were immune from commercial exploitation, the reproductive potential of the stocks was believed to be maintained at high, pre-fishery levels despite heavy fishing pressure on large males. However, in the present paper, we observed that up to 46% of the landed males (≥95 mm CW) were morphometrically immature. Thus, it may be that, if the morphometrically males are not reproductively competent, the reproductive potential of the stocks is not as well protected as previously postulated; and, conceivably, in some situations overall reproductive output could be seriously reduced due to a lack of functionally mature males. A complexing issue is that many males attain a terminal molt to morphometric maturity below the legal minimum size. Accumulations of these "pygmy" males appear to represent a wasted portion of the resource, a sink that may also act to depress growth and recruitment into the fishery by utilizing scarce food and spatial resources. A potential benefit of pygmy males might be to provide partners for mating females in the absence of larger, functionally mature males; however, if such were the case, there remains a risk that the increased genetic impact of the pygmies could produce strong selective pressures for dwarfism in the stocks. On balance, the optimal management strategy (in terms of yield-per-recruit, and ecology) would seem to involve harvesting morphometrically mature males, including the pygmies, and leaving the morphometrically immature males to grow and mature. While reducing or

raising the legal minimum CW would result in either an even greater proportion of morphometrically immature males being exploited or an even larger sink of pygmies, respectively, imposition of a minimum chela size regulation could probably come close to achieving the desired goals. Specifically, a ring gauge set to the chela size that most effectively partitions the morphometrically immature data swarm from the morphometrically mature data swarm should enable fishermen to distinguish most males in terminal molt and allow a differential harvesting strategy. We advocate introduction of a ring gauge to experimentally test the influence of pygmy males over, say, a 5-yr period in Area 5. During the course of the test period it would be essential to monitor female fecundity and male production patterns in both the experimental area and an adjacent control area (Area 6).

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O'Halloran, M.J. 1985. Molt cycle changes and the control of moult in male snow crab, Chionoecetes opilio. M.Sc. Thesis, Dalhouse University, (Halifax, N.S.): 183 p.

Table 1. Snow crab statistics for the Atlantic coast of Cape Breton Island, 1978-87.

Area	Year	No. of licensed boats	No. of active boats	No. of logbooks received	Landing Statistics: Area Managers (kg)	Landing Statistics: logbooks (kg)	Actual effort in traps hauled (logbook data) (all trap types combined)
2	1978	-	-	-	-	-	-
	1979	12	8	3	108,005	14,129	1,739
	1980	12	8	3	46,919	10,240	1,276
	1981	13	6	-	4,695	-	-
	1982	13	-	-	-	-	-
	1983	13	12	2	7,130	248	150
	1984	5	2	-	9,593	-	-
	1985	5	-	-	-	-	-
	1986	5	1	1	56	56	30
	1987	4	3	-	529	-	-
3	1978	36	16	16	-	91,118	7,863
	1979	36	27	27	185,101	164,110	18,124
	1980	36	31	25	139,686	73,988	13,835
	1981	36	22	1	31,215	816	60
	1982	35	20	18	86,814	75,295	9,388
	1983	35	27	27	40,058	40,172	8,217
	1984	37	19	13	14,649	12,839	4,346
	1985	40	10	10	13,537	12,732	3,220
	1986	40	12	8	5,632	5,805	2,306
	1987	32	21	14	59,756	56,826	8,137
4	1978	38	11	11	-	305,076	11,268
	1979	38	35	26	624,029	591,580	22,775
	1980	38	26	18	181,241	136,605	7,543
	1981	37	11	3	61,476	6,545	520
	1982	37	21	20	165,395	116,243	6,138
	1983	38	24	18	44,199	31,612	4,341
	1984	37	7	6	17,581	18,141	2,173
	1985	37	4	4	406	568	156
	1986	37	7	2	16,744	4,333	729
	1987	34	15	12	58,671	49,096	4,801
5	1978	15	15	15	-	250,076	6,165
	1979	25	24	23	679,504	682,731	15,382
	1980	26	24	21	395,855	324,786	9,261
	1981	25	11	10	90,463	81,819	3,135
	1982	25	19	18	300,145	298,469	9,931
	1983	22	21	21	151,296	148,827	8,146
	1984	24	10	6	45,215	41,295	2,220
	1985	24	5	5	29,171	20,833	1,465
	1986	24	7	6	43,972	40,155	2,837
	1987	21	14	11	157,408	119,321	4,547
6	1979	8	4	4	24,868	27,351	1,880
	1980	11	10	9	58,596	69,136	5,246
	1981	11	5	5	15,896	20,350	1,316
	1982	11	7	7	63,072	63,133	6,462
	1983	14	13	12	64,084	64,461	7,733
	1984	14	13	13	53,889	50,239	5,229
	1985	14	6	5	40,844	32,219	3,157
	1986	14	5	5	37,770	49,027	4,119
	1987	13	11	9	83,931	77,782	6,021
Total	1978	89	42	42	-	646,270	25,296
	1979	119	98	83	1,621,508	1,479,901	59,900
	1980	123	99	76	822,287	614,755	37,161
	1981	122	55	19	203,745	109,530	5,031
	1982	121	67	63	615,426	553,140	31,919
	1983	122	97	80	306,767	285,320	28,587
	1984	117	51	37	140,927	122,514	13,968
	1985	120	25	24	83,958	66,352	7,998
	1986	120	32	22	104,174	99,376	10,021
	1987	104	64	48	360,295	303,025	23,506

Table 2. Comparsion of assessment data for Cape Breton Island snow crab (Areas 2-6) 1978-87.

Area	Year	No. of active boats	No. of logbooks received	Landing Statistics: Area Managers (kg)	Landing Statistics: logbooks† (kg)	Effort (standardized trap hauls)	Mean CPUE	Available Biomass for Season (mt)	Exploitation rate (%)	Standardized trap type
2,3 & 4	1978	27	23	-	192,228	17,258	11.14	-	-	(1.2X.9X.8m,wood)
(inshore)	1979	70	40	917,136	262,250	25,660	10.22	324.9	81	"
	1980	65	42	367,846	181,033	17,499	10.35	225.2	80	"
	1981	39	4	97,386	7,361	580	12.69	-	-	(1.5X1.5X.5m,steel)
	1982	41	28	252,209	100,161	13,971	7.17	153.0	65	(1.2X.9X.8m,wood)
	1983	63	41	91,387	55,242	11,780	4.69	76.5	72	"
	1984	28	18	41,823	16,423	5,382	3.05	24.2	68	"
	1985	14	14	13,943	13,300	3,376	3.94	-	-	"
	1986	19	11	13,712	10,194	3065	3.33	20.2	51	"
	1987	39	26	118,956	105,922	12,938	8.20	229.2	46	"
4	1978	*	4	-	203,966	4,916	41.49	-	-	(1.5X1.5X.5m,steel)
(offshore)	1979	*	16	*	507,569	10,546	48.13	-	-	"
	1980	*	4	*	39,800	827	48.13	790.0	64	"
	1981	*	-	*	-	-	-	-	-	"
	1982	*	10	*	91,377	2,875	31.78	-	-	"
	1983	*	6	*	16,790	1,454	11.55	-	-	"
	1984	*	2	*	14,557	1,159	12.56	28.3	51	"
	1985	*	-	*	-	-	-	-	-	"
	1986	1	-	8,720	-	-	-	-	-	"
	1987	0	0	0	0	0	0	0	0	0
5	1978	15	15	-	250,076	4,531	55.19	440.0	57	"
	1979	24	23	679,504	682,731	14,747	46.30	1185.0	58	"
	1980	24	21	395,855	324,786	7,341	44.24	543.0	60	"
	1981	11	10	90,463	81,819	2,835	28.86	-	-	"
	1982	19	18	300,145	298,469	8,848	33.73	356.9**	84	"
	1983	21	21	151,296	148,827	7,261	20.50	176.0**	85	"
	1984	10	6	45,215	41,295	2,336	17.68	55.3	75	"
	1985	5	5	29,171	20,833	1,465***	14.22		-	"
	1986	7	6	43,972	40,155	2,837***	14.15	72.9	55	"
	1987	14	11	157,408	119,321	4,547	26.24	293.4	41	"
6	1979	4	4	24,868	27,351	1,880	14.55	69.4	39	(1.5X1.5X.5m,steel)
	1980	10	9	58,586	69,136	5,246	13.18	177.0	39	"
	1981	5	5	15,896	20,350	1,316	15.46	35.8	57	"
	1982	7	7	63,072	63,133	6,462	9.77	175.0	36	"
	1983	13	12	64,084	64,461	7,614	8.47	102.7	63	"
	1984	13	12	53,889	50,239	5,229	9.61	-	-	"
	1985	6	5	40,844	32,219	3,157	10.21	-	-	"
	1986	5	5	37,770	49,027	4,119	11.90	69.2	71	"
	1987	11	9	83,931	77,782	6,021	12.92	181.7	43	"
Total	1978	46	42	-	646,270	26,705	24.20			All traps types combined
	1979	98	83	1,621,508	1,479,901	52,833	28.01			"
	1980	99	76	822,287	614,755	30,913	19.89			"
	1981	55	19	203,745	109,530	4,731	23.15			"
	1982	67	63	615,426	553,140	32,156	17.20			"
	1983	97	80	306,767	285,320	28,109	10.15			"
	1984	51	37	140,927	122,514	14,106	8.69			"
	1985	25	24	83,958	66,352	7,998	8.30			"
	1986	32	22	104,174	99,376	10,021	9.92			"
	1987	64	48	360,295	303,025	23,506	12.89			"

† utilizable

* landings included in Area 3

** from tagging, all other estimates from Leslie analysis of logbook data

*** Japanese conical traps combined with steel trap (1.5 X 1.5 X 0.5m)

Table 3. Compilation of shell hardness and egg presence data for male and female snow crabs sampled in-port and at-sea for Cape Breton (areas 2,3,4,5 and 6) for the 1987 fishing season.

Area	No. of Males	n(%) Hard Shell	n(%) Medium Shell	n(%) Soft Shell	No.of Females	n(%) Hard Shell	n(%) Without Eggs
2	592	589(99.49)	2(0.34)	1(.17)	38	38(100)	1(2.6)
3	1497	1486(99.27)	11(.73)		201	201(100)	1(.5)
4	885	885(100)			176	176(100)	0
5	937	937(100)			284	284(100)	3(1.06)
6	980	980(100)			247	247(100)	4(1.62)
Total	4891	4877(99.71)	13(0.27)	1(.02)	946	946(100)	9(.95)

Table 4. Catch and effort statistics from logbook data for the snow crab fishery in 1987.

Areas 2,3 & 4

Week Period	Trap Hauls	Catch (kg)	CPUE (kg/trap haul)	Cumulative Catch (Kg)
July 22-28	1486	16267	11.0	8133.5
July 29-Aug. 4	2418	24999	10.3	28766.5
Aug. 5-11	3034	23886	7.9	53209.0
Aug. 12-18	1829	14318	7.8	72311.0
Aug. 19-25	1778	10922	6.1	84931.0
Aug. 26-Sept. 1	1324	8335	6.3	94559.5
Sept. 2-8	652	4399	6.8	100926.5
Sept. 9-15	417	2796	6.8	104524.0
Total	12938	105922	8.2	

Area 5

Week Period	Trap Hauls	Catch (kg)	CPUE (kg/trap haul)	Cumulative Catch (Kg)
July 22-28	446	16146	36.2	8073.0
July 29-Aug. 4	1002	24668	24.6	28480.0
Aug. 5-11	947	30693	32.4	56160.5
Aug. 12-18	674	14962	22.2	78988.0
Aug. 19-25	565	13349	23.6	93143.5
Aug. 26-Sept. 1	456	9936	21.8	104786.0
Sept. 2-8	215	5051	23.5	112279.5
Sept. 9-15	242	4516	18.7	117063.0
Total	4547	119321	26.2	

Area 6

Week Period	Trap Hauls	Catch (kg)	CPUE (kg/trap haul)	Cumulative Catch (Kg)
Aug. 2-7	945	16562	17.5	8281.0
Aug. 8-14	1008	14182	14.1	23653.0
Aug. 15-21	864	10953	12.7	36220.5
Aug. 22-28	939	10918	11.6	47156.0
Aug. 29-Sept. 4	611	7038	11.5	56135.0
Sept. 5-11	601	7143	11.9	63224.5
Sept. 12-18	568	6363	11.2	69977.5
Sept. 19-25	327	2970	9.1	74644.0
Sept. 26-30	158	1653	10.5	76955.5
Total	6021	77782	12.9	

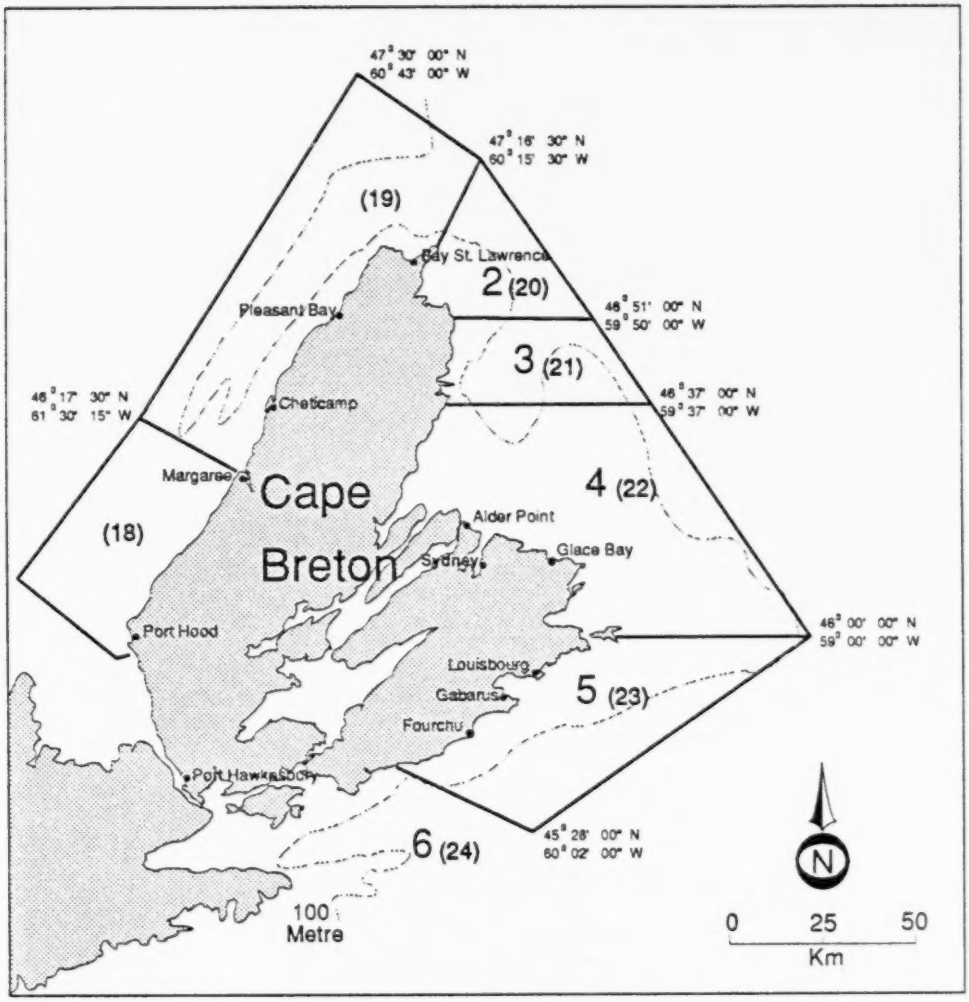


Fig. 1 Cape Breton Island snow crab fishing areas.

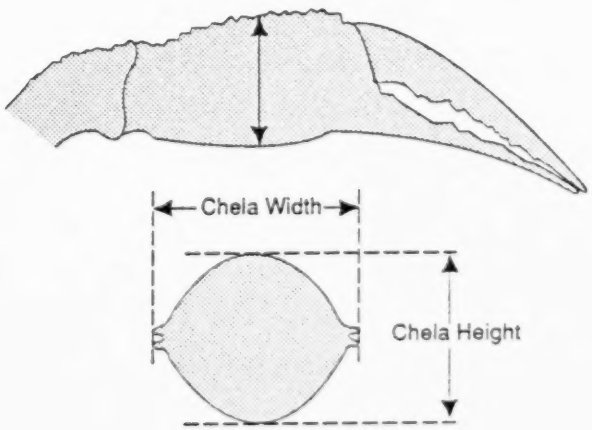


Fig. 2 Diagram of a male snow crab chela. Note: chela width and chela height dimensions.

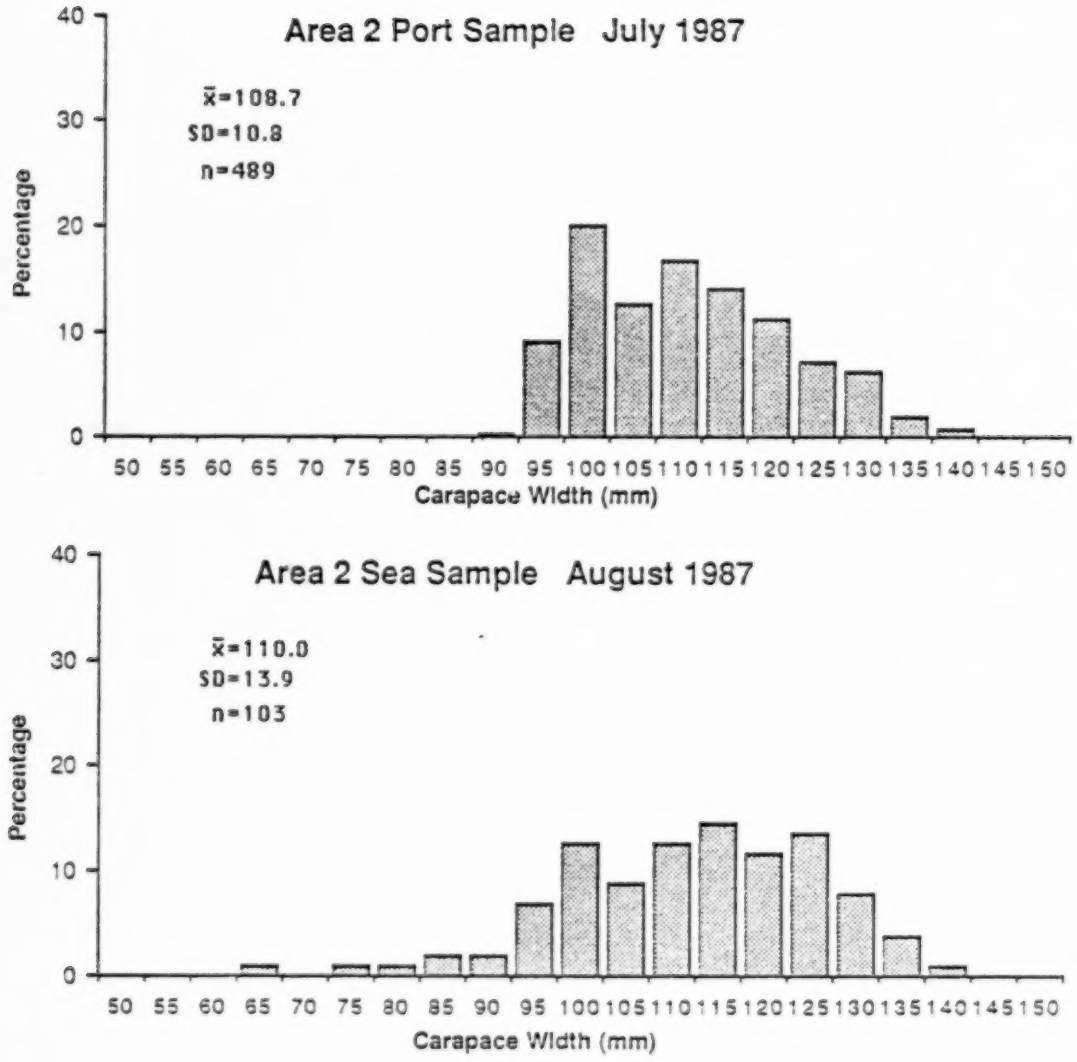


Fig. 3. Size frequency histograms for male snow crabs sampled in-port and at-sea from commercial vessels in Area 2 during July-August of the 1987 fishing season.

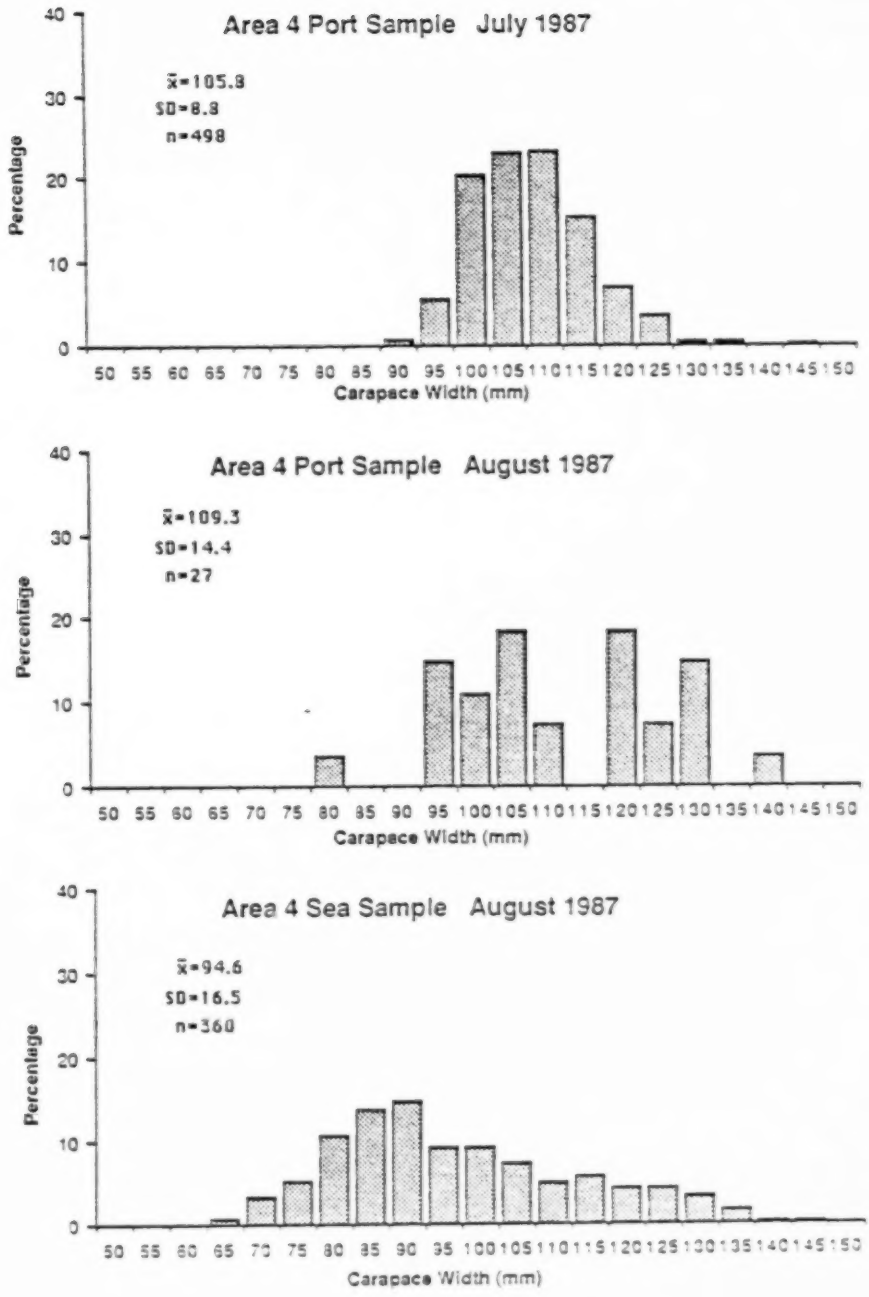


Fig. 4. Size frequency histograms for male snow crabs sampled in-port and at-sea from commercial vessels in Area 4 during the 1987 fishing season.

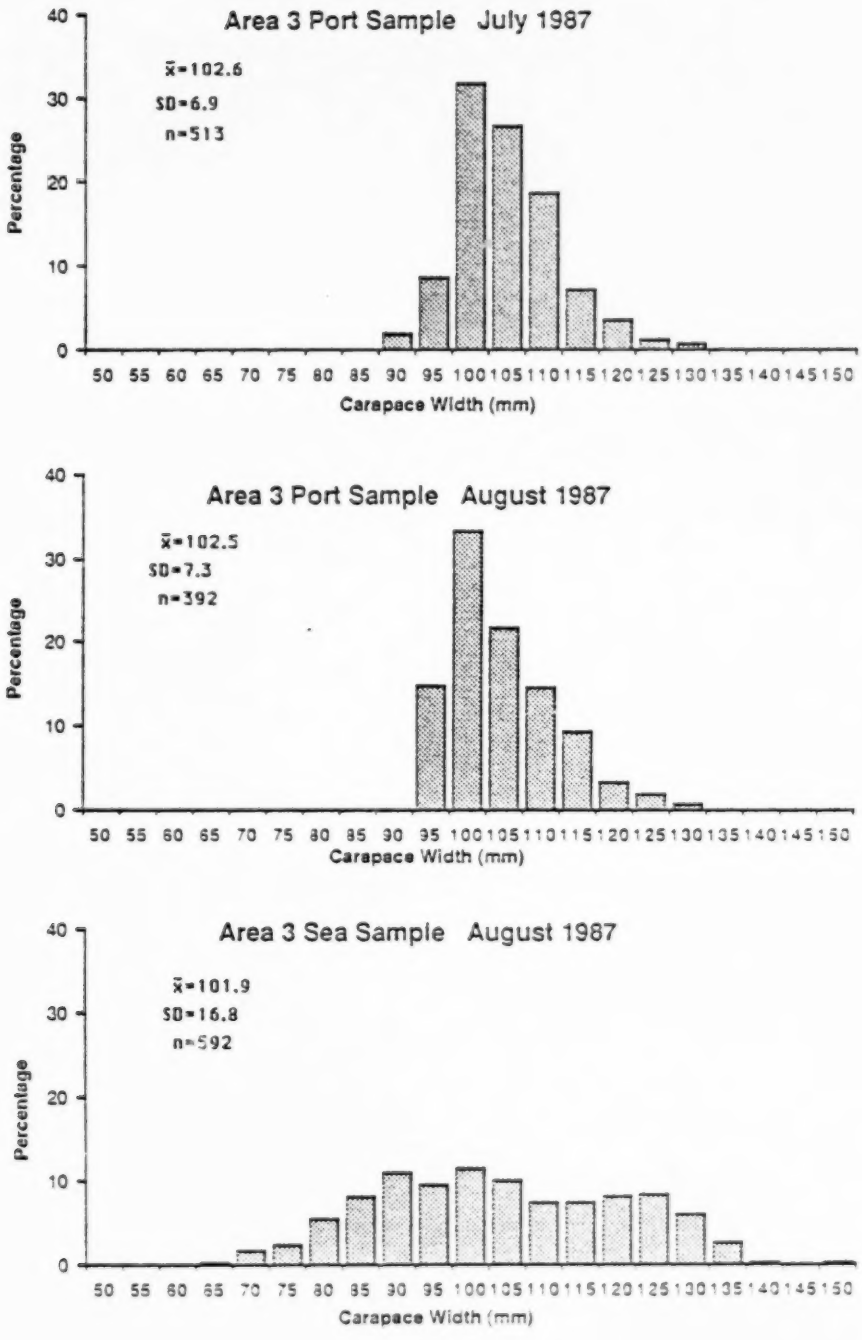


Fig. 5. Size frequency histograms for male snow crabs sampled in-port and at-sea from commercial vessels in Area 3 during the 1987 fishing season.

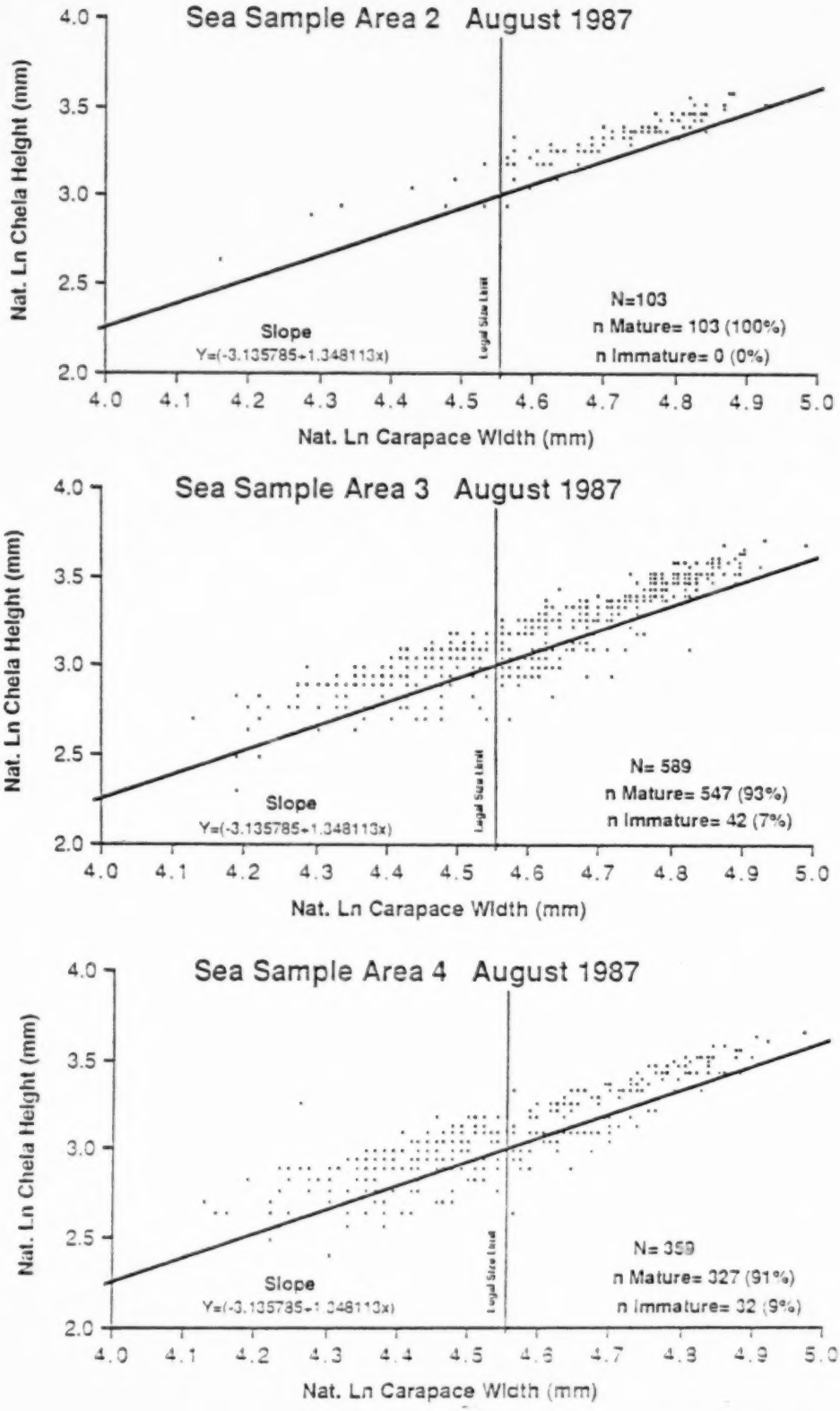


Fig. 6. Graphs showing the relationship between the natural logarithms of the chela height and the natural logarithms of the carapace width for male snow crabs sampled at-sea from commercial vessels in Areas 2,3 and 4 during August of the 1987 fishing season.

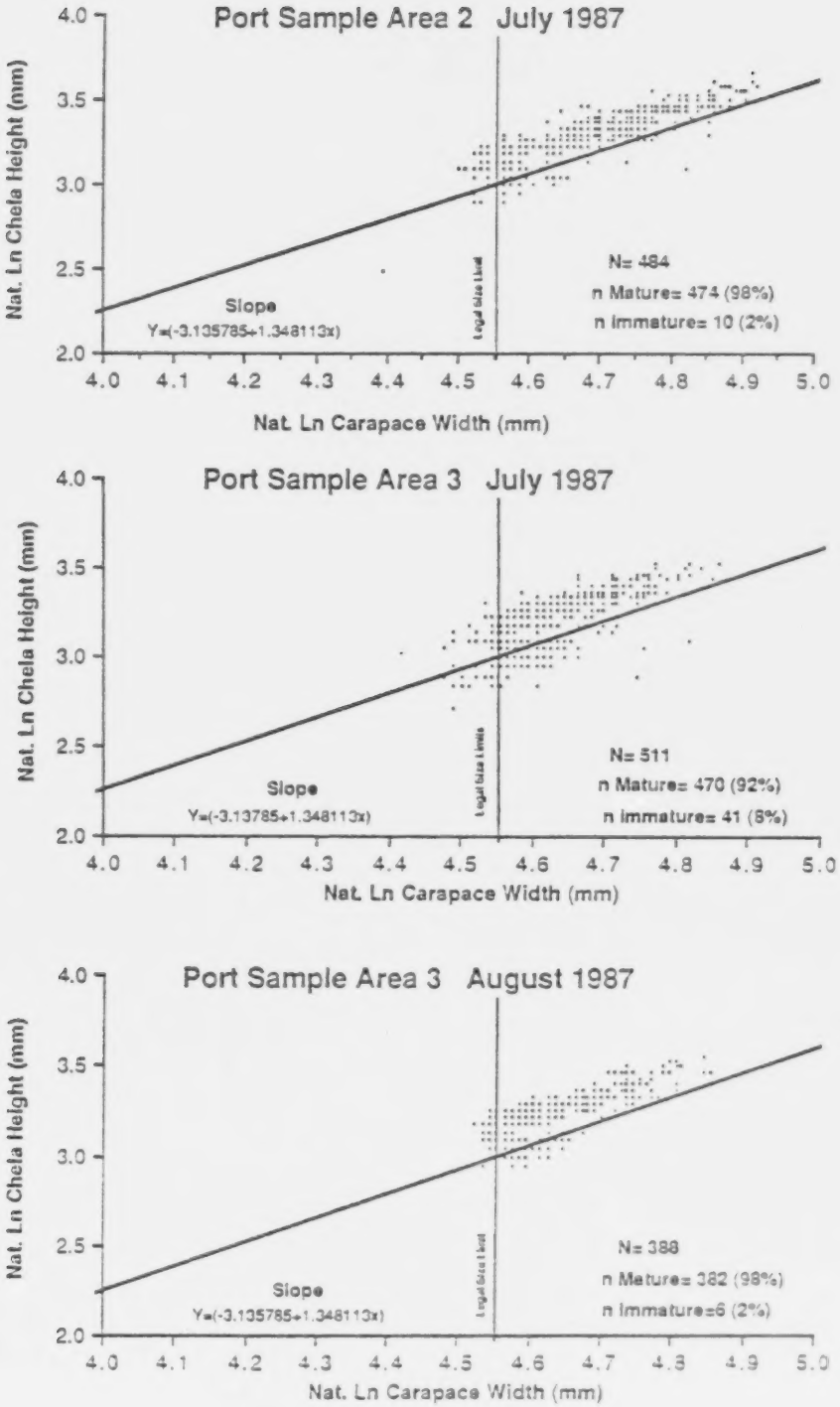


Fig. 7. Graphs showing the relationship between the natural logarithms of the chela height and the natural logarithms of the carapace width for male snow crabs sampled in-port from commercial vessels in Areas 2 and 3 during the 1987 fishing season.

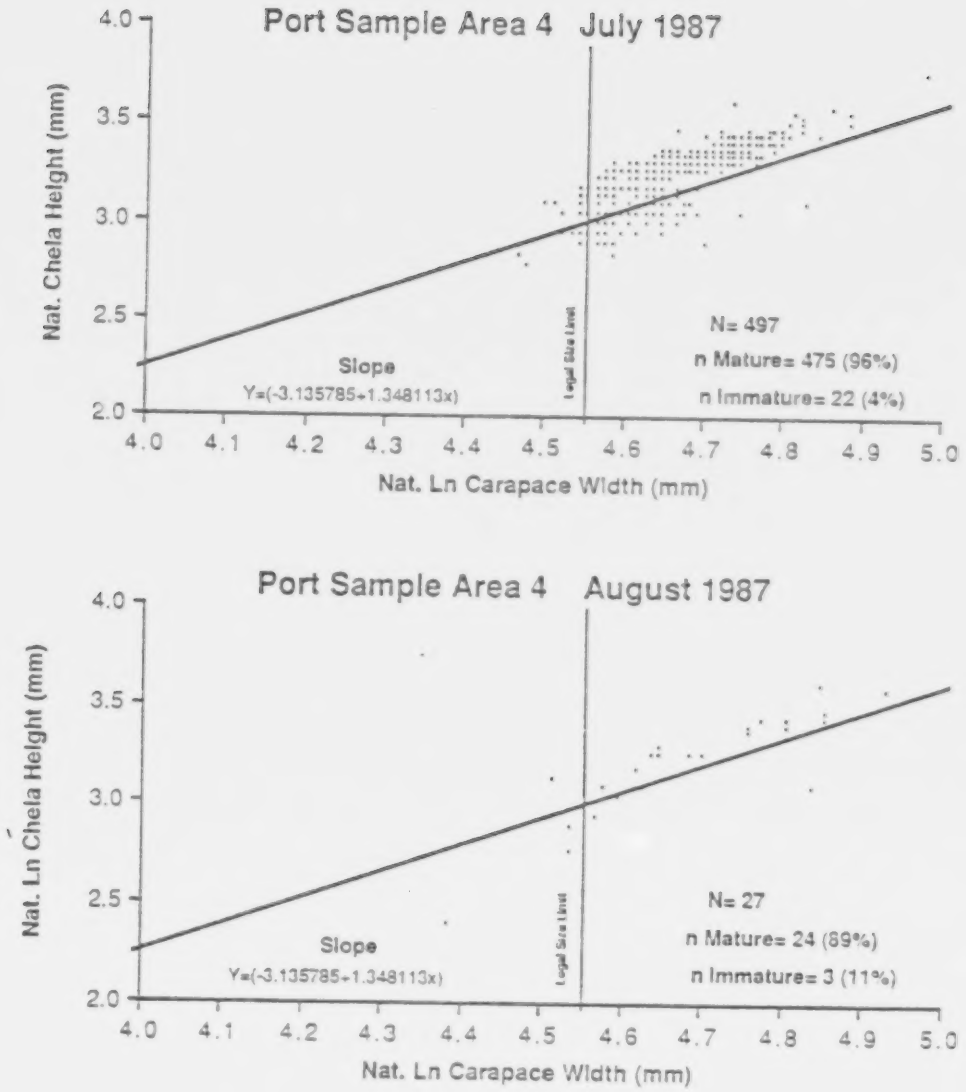


Fig. 8. Graphs showing the relationship between the natural logarithms of the chela height and the natural logarithms of the carapace width for male snow crabs sampled in-port from commercial vessels in Area 4 during the 1987 fishing season.

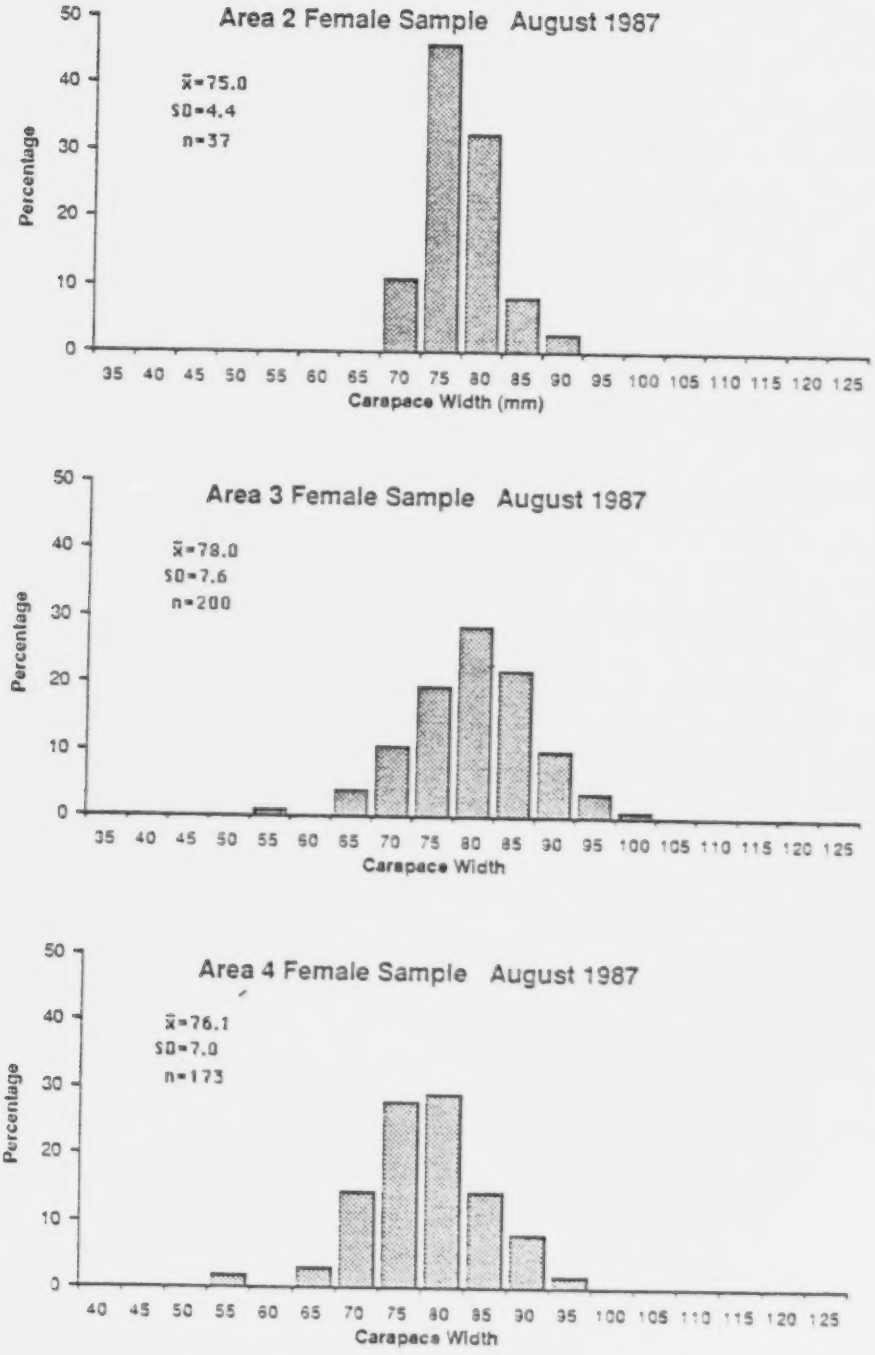


Fig.9. Size frequency histograms of mature female snow crabs sampled at-sea from commercial vessels in Areas 2,3 and 4 during August of the 1987 fishing season.

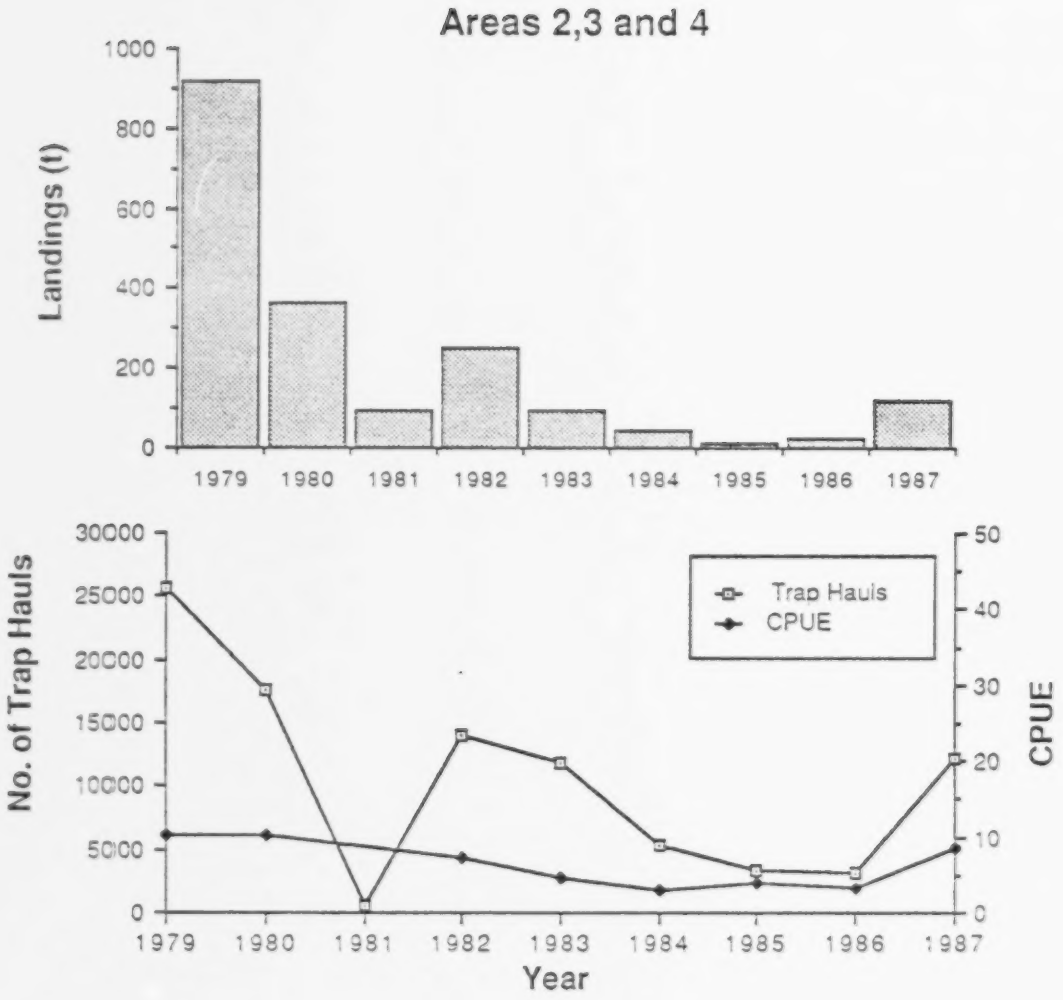
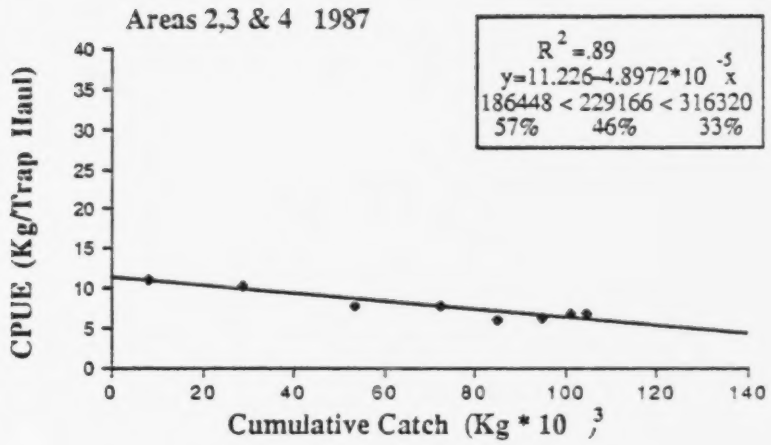
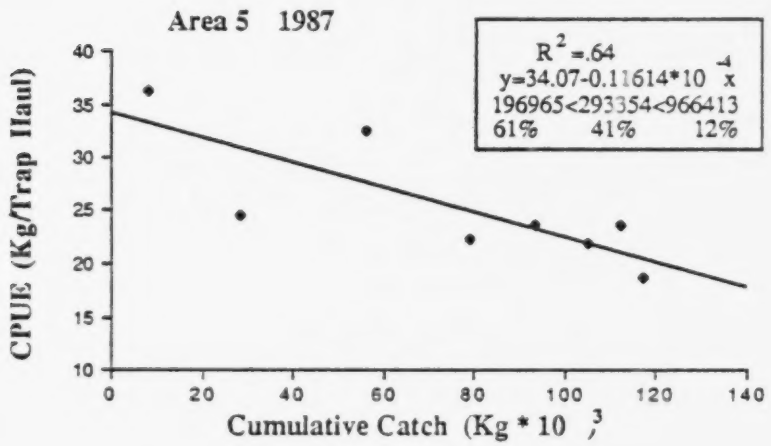
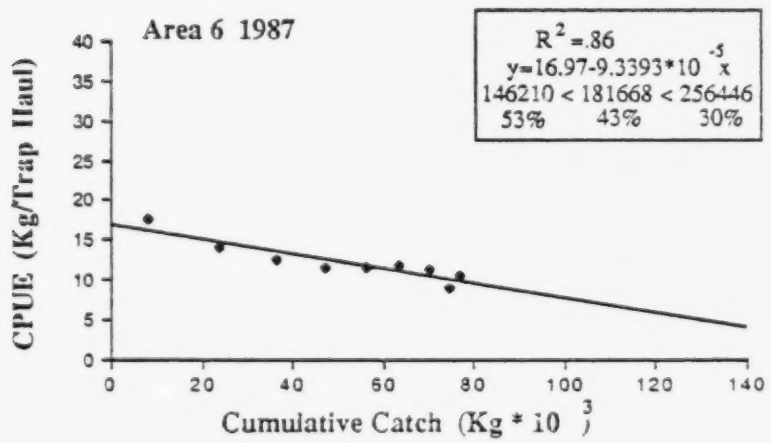


Fig. 10. Historical series (1979-1987) of data on landings, effort and CPUE (kg. trap haul^{-1}) for the snow crab fishery Areas 2,3 and 4 (inshore).







Key

- * R 2 = coefficient of determination
- * Equation for regression on data
- * Leslie estimate of commercial biomass (kg) showing 95% confidence limits
- * Exploitation rate from Leslie estimate showing 95% confidence limits

Fig. 11. Graphs of cumulative weekly landings against CPUE, from logbook data for a) Areas 2,3 and 4; b) Area 5; and c) Area 6 in 1987 and Leslie estimates of commercial biomass and exploitation rate.

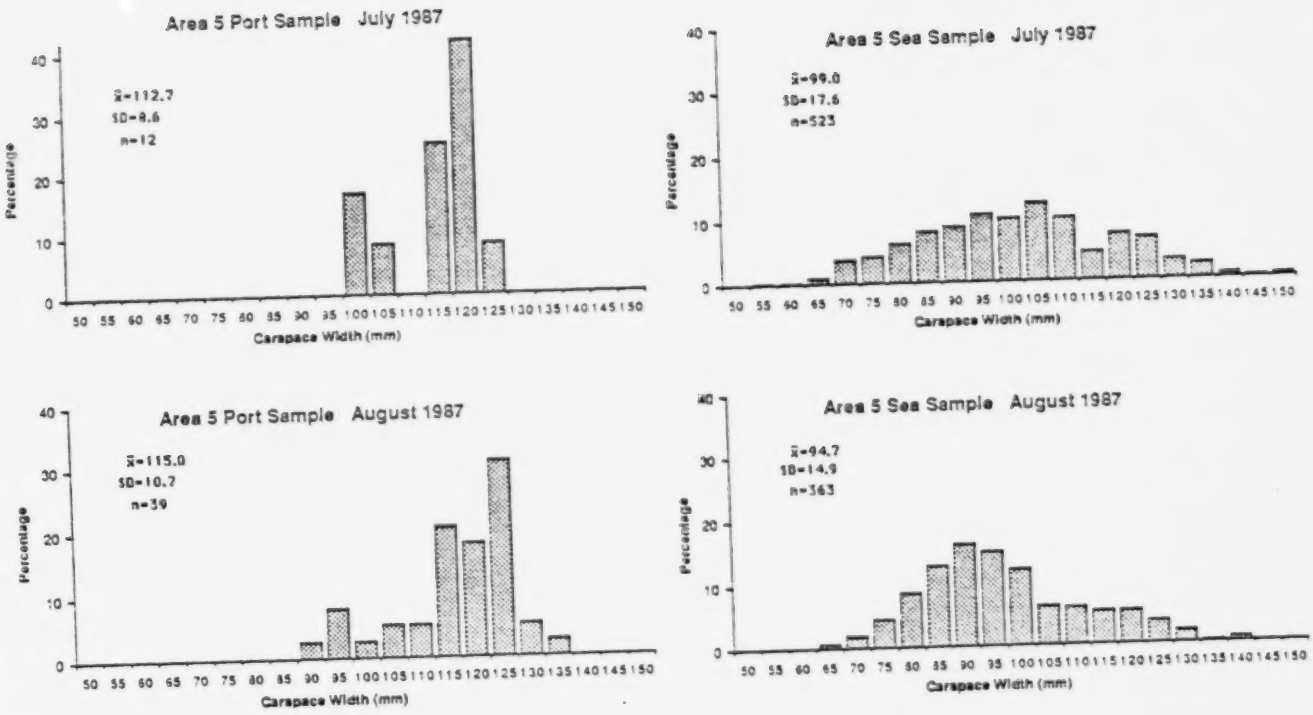


Fig. 12. Size frequency histograms for male snow crabs sampled in-port and at-sea from commercial vessels in Area 5 during the 1987 fishing season.

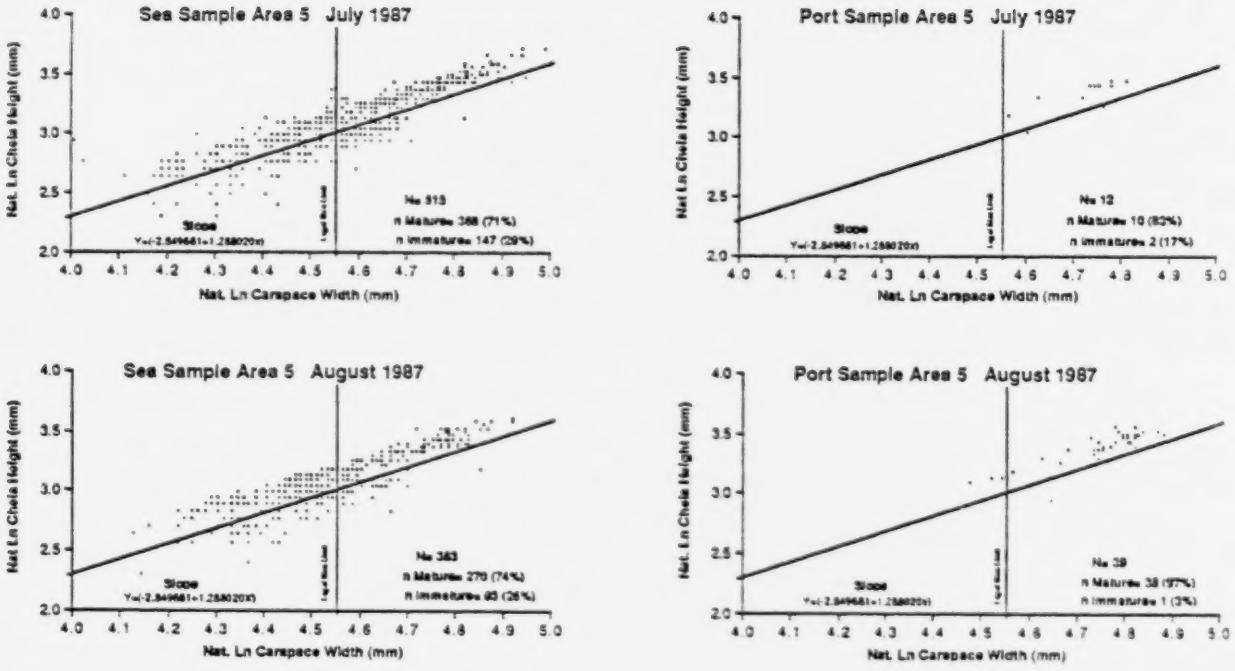

Sea Sample Area 5 July 1987
Port Sample Area 5 July 1987
Sea Sample Area 5 August 1987
Port Sample Area 5 August 1987
Nat. Ln Chela Height (mm)
Nat. Ln Carapace Width (mm)
Slope
n Mature
n Immature

Fig. 13. Graphs showing the relationship between the natural logarithms of the chela height and the natural logarithms of the carapace width for male snow crabs sampled at-sea and in-port from commercial vessels in Area 5 during the 1987 fishing season.

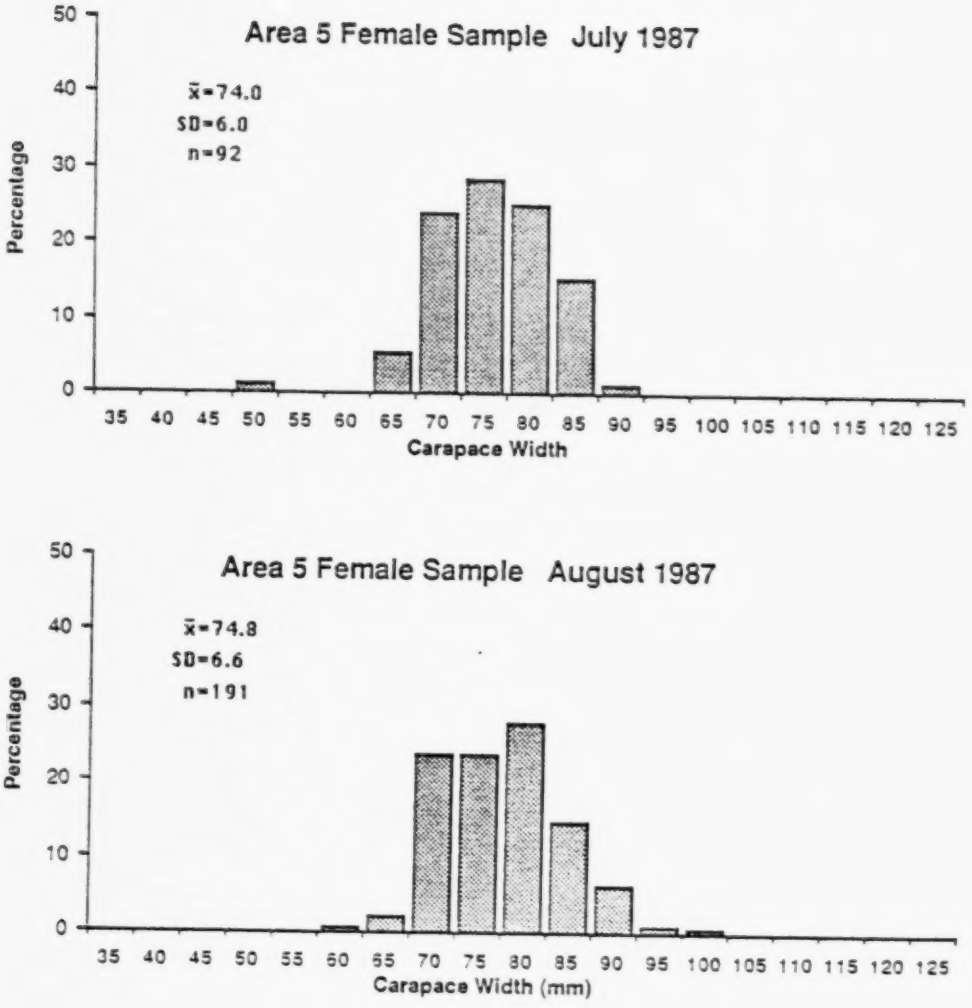


Fig.14. Size frequency histograms of mature female snow crabs sampled at-sea from commercial vessels in Area 5 during the 1987 fishing season.

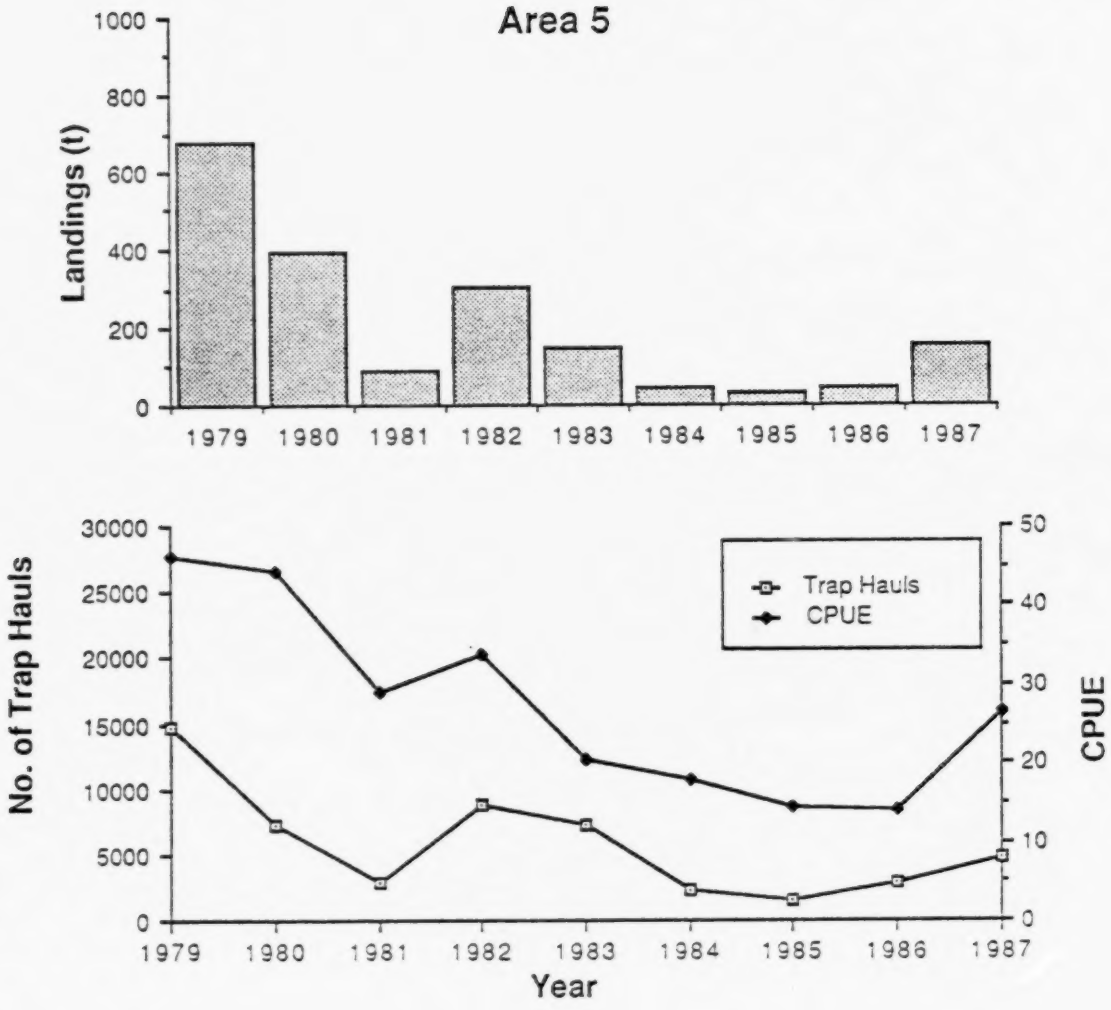


Fig. 15. Historical series (1979-1987) of data on landings, effort and CPUE (kg. trap haul^{-1}) for the snow crab fishery in Area 5.

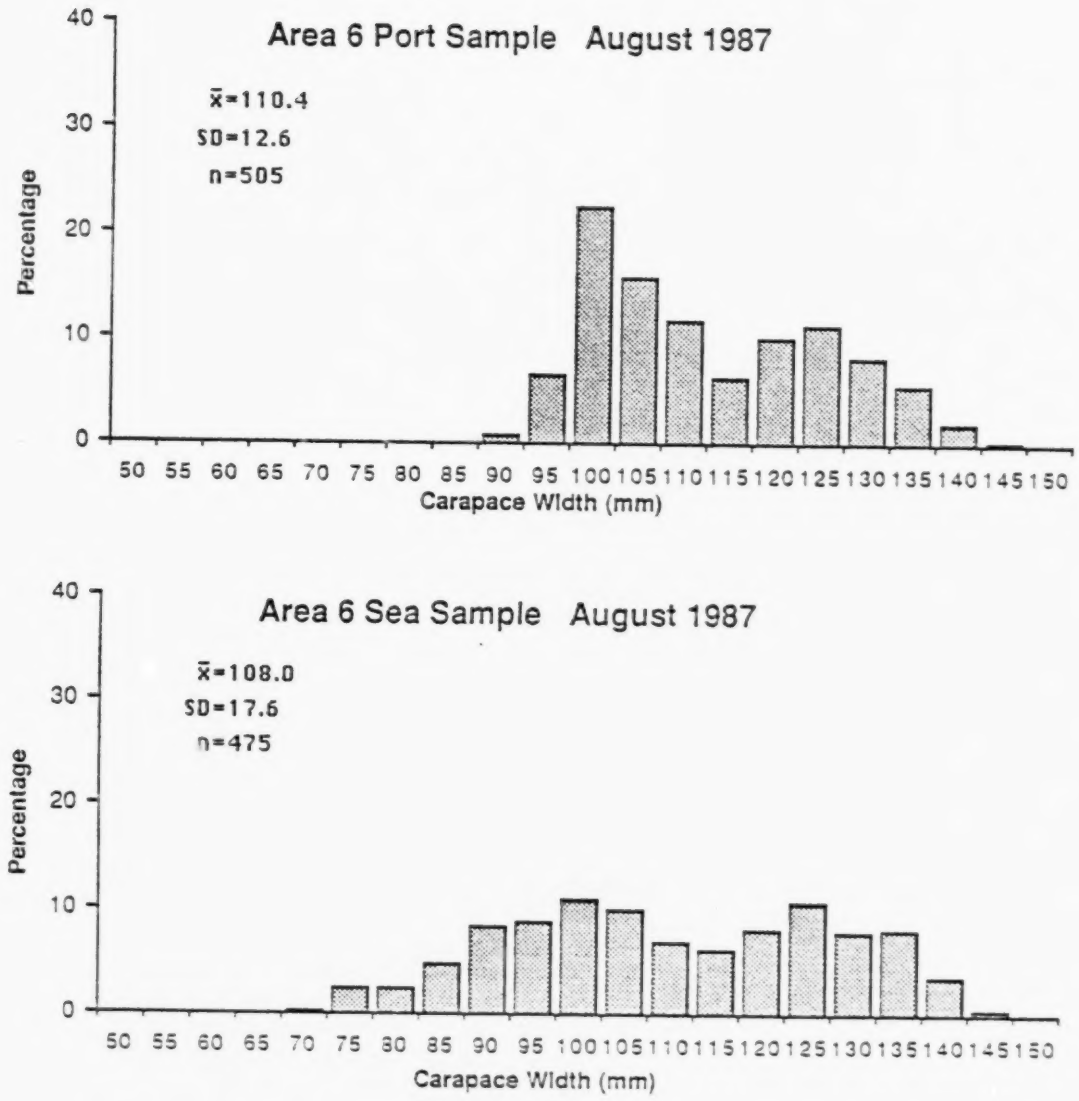


Fig. 16. Size frequency histograms for male snow crabs sampled in-port and at-sea from commercial vessels in Area 6 during August of the 1987 fishing season.

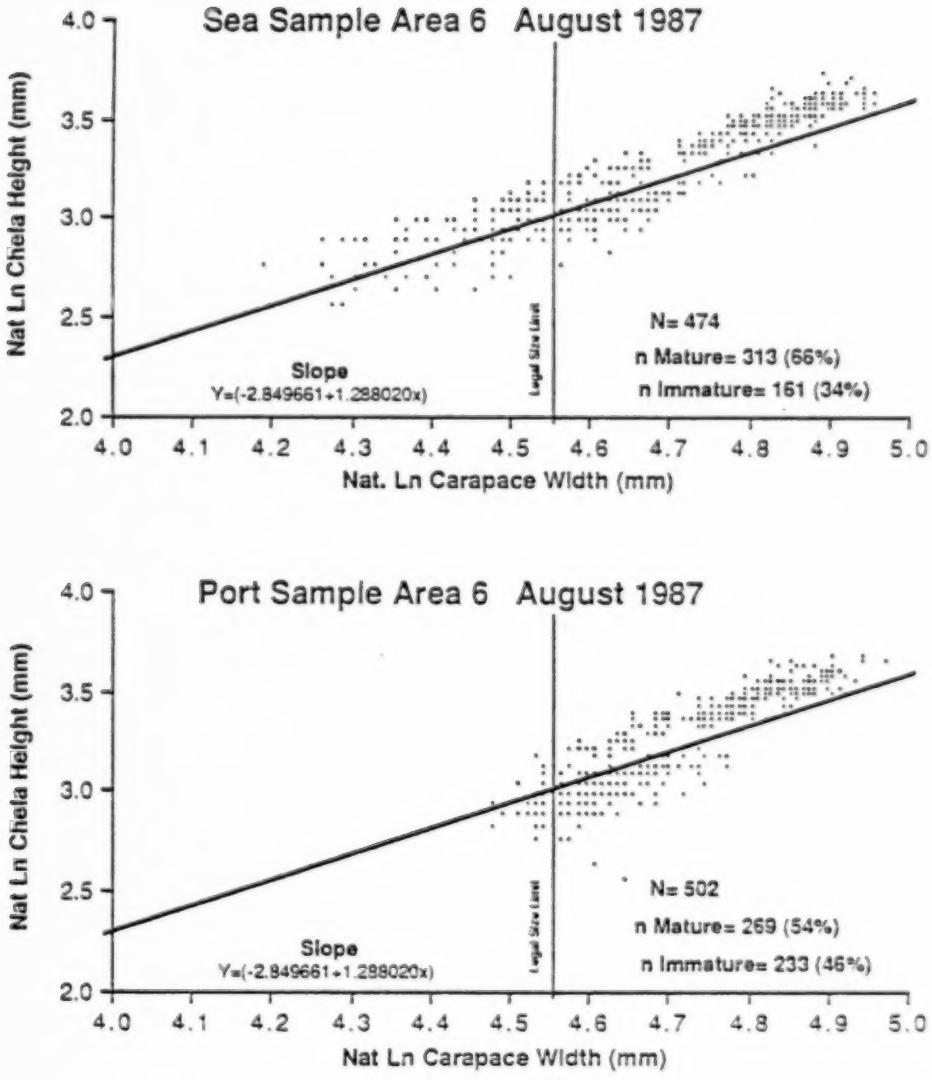


Fig. 17. Graphs showing the relationship between the natural logarithms of the chela height and the natural logarithms of the carapace width for male snow crabs sampled at-sea and in-port from commercial vessels in Area 6 during the 1987 fishing season.

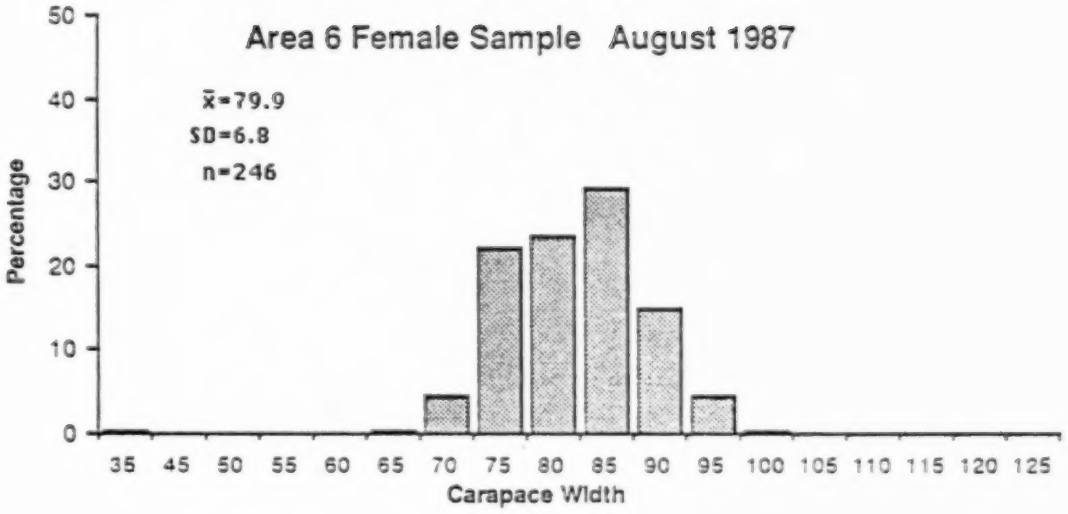


Fig.18. Size frequency histograms of mature female snow crabs sampled at-sea from commercial vessels in Area 6 during the 1987 fishing season.

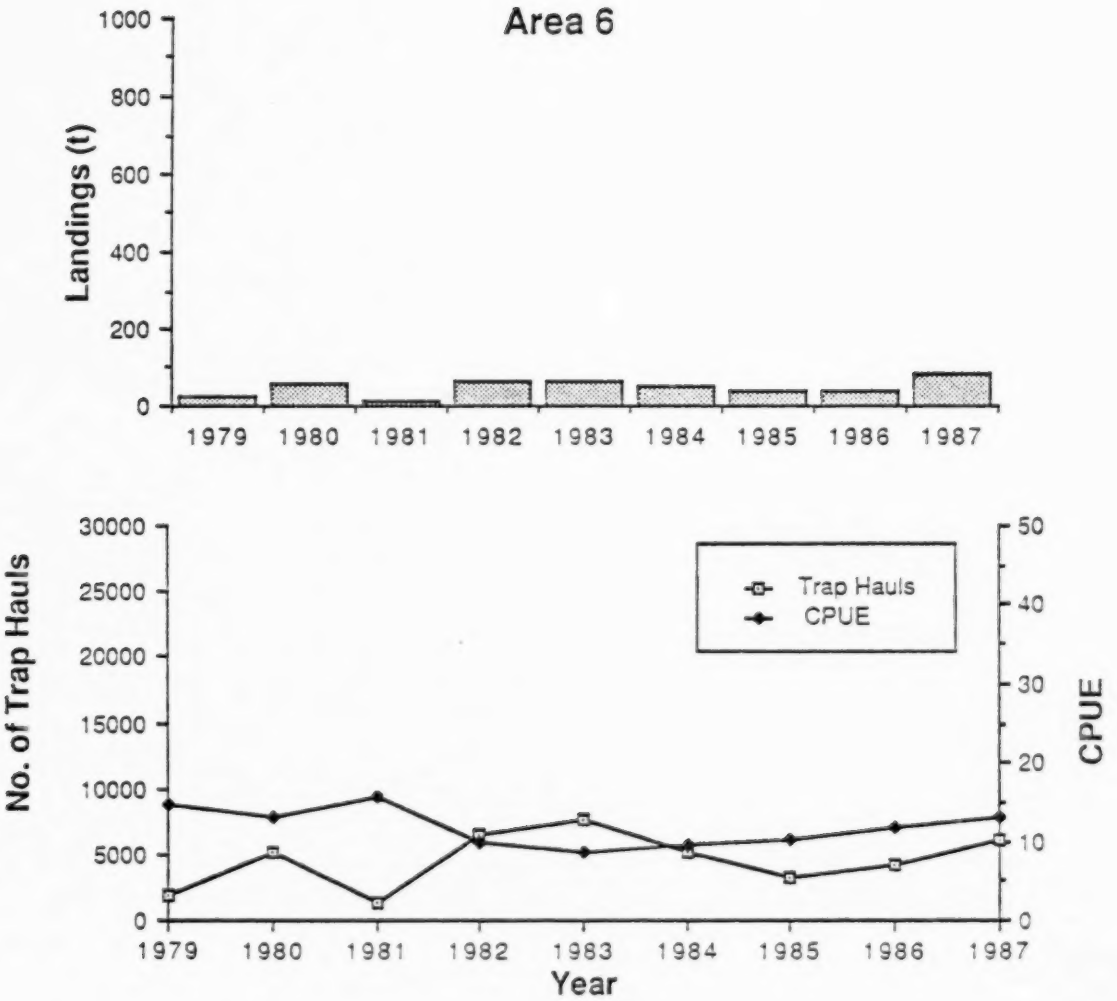


Fig. 19. Historical series (1979-1987) of data on landings, effort and CPUE (kg. trap haul^{-1}) for the snow crab fishery in Area 6.

PORT SAMPLE: _____
SEA SAMPLE : _____
INSHORE : _____
OFFSHORE: _____

DATE: _____

Snow Crab Sampling Sheet

NAME OF VESSEL : _____
NAME OF SKIPPER: _____
PORT LOCATION : _____

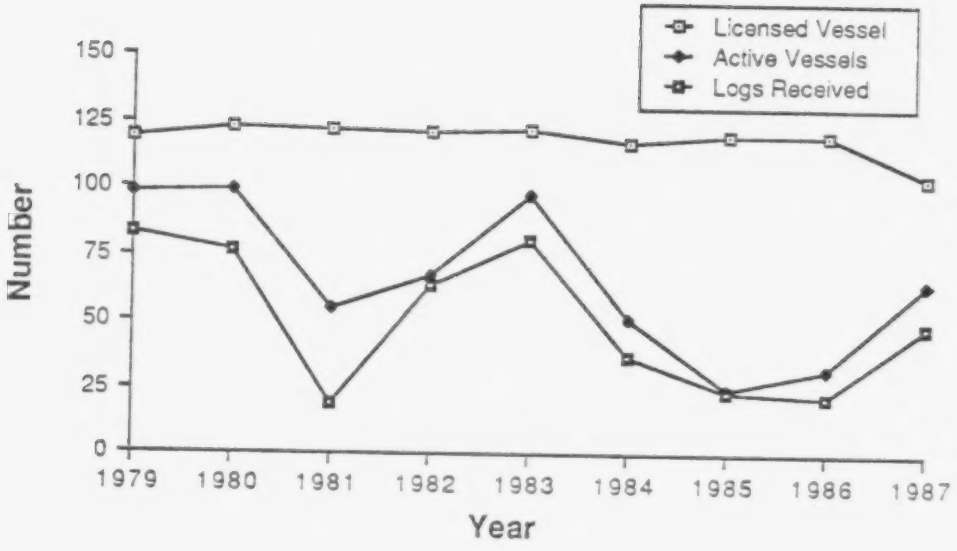
AREA FISHED: _____
LOCATION : _____
DEPTH : _____

Carap. width (mm)	Right claw (mm)	Chela height (mm)	Shell hardness H M S	Shell condition New Old	Sex M F	Egg color	Egg clutch size Missing Full	Tag number

Appendix II. Discriminant functions, as determined by M. Comeau, to separate morphometrically mature male snow crabs for Area 4 and Area 5, Cape Breton Island.

Discriminant functions (immature: Y<0; mature; Y>0)	% assigned to right group
Area 4 Chela height (CH)	
$Y= 0.613255\ Log_eCH - 0.803159\ Log_eCW + 1.868191$	99.0%
Equation of cutting line: $Log_eCH= -3.135785 + 1.348113\ Log_eCW$	
Area 5 Chela height (CH)	
$Y= 0.612581\ Log_eCH - 0.789885\ Log_eCW + 1.747569$	99.0%
Equation of cutting line: $Log_eCH= -2.849661 + 1.288020\ Log_eCW$	
Area 5 Chela Width (LAP)	
$Y= 0.612581\ Log_eLAP - 0.790408\ Log_eLAP + 1.880194$	98.3%
Equation of cutting line: $Log_eLAP= -3.06930 + 1.290291\ Log_eCW$	

Normal deviate indicating probability for an individual to pertain to either group	
IMMATURES	
$Z= (118.7019\ Log_eCW - 88.0504\ Log_eCH - 286.7692)/4.6502$	ZONE 4
$Z= (125.5644\ Log_eCW - 97.4864\ Log_eCH - 288.8037)/4.7248$	ZONE 5
$Z= (65.3824\ Log_eCW - 50.6726\ Log_eLAP - 164.2051/4.2324$	ZONE 5
MATURES	
$Z= (118.7019\ Log_eCW - 88.0504\ Log_eCH - 265.1445)/4.6502$	ZONE 4
$Z= (125.5644\ Log_eCW - 97.4864\ Log_eCH - 266.4802)/4.7248$	ZONE 5
$Z= (65.3824\ Log_eCW - 50.6726\ Log_eLAP - 146.2918)/4.2324$	ZONE 5



Appendix III. Statistical display of numbers of snow crab vessels licensed, active and logbooks received for Cape Breton Areas 2-6 for the period 1978 - 1987.